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Summary Progress Report No. 4

Covering the Period
1 July 1956 through 31 December 1956

Title: ANALYSIS OF SELECTED DISSEMINATION AND DESIGN PROBLEMS (U)

Prepared By

Fred B. Smith
Harold D. Black
George Fejer
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November 20, 1957

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ANALYSIS OF SELECTED DISSEMINATION AND DESIGN PROBLEMS (U)

ABSTRACT

This program is to supply information required for the development of new or improved chemical munitions. Progress is reported for the following tasks: Task II - Use of CW Agents in Recoilless Rifle Ammunition for Defeat of Field Fortifications; Task III - Exploitation of Toxic CW in Tactical Situations Using Ground-to-Ground Munitions; Task VII - Critical Analysis of Dissemination Program; Task IX - High Altitude Spray from Aircraft and Guided Missiles; Task X - Ground-to-Ground Rockets for Large Area CW Coverage; Task XI - New Concepts for the Optimum Delivery of CW Agents; Task XII - Investigate the Feasibility of Producing "Toxic Rain".

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

ANALYSIS OF SELECTED DISSEMINATION AND DESIGN PROBLEMS (U)

Summary Progress Report No. 4

Covering the Period
1 July 1956 through 31 December 1956

I. INTRODUCTION

This program is to supply information necessary for the development of new or improved munitions. Work is performed according to task assignments, each of which defines a problem to be investigated or specifies services to be rendered. No experimental work is conducted in this project. The experience of ARF personnel, information supplied by personnel of the Chemical Corps and other agencies, information available in the literature, basic physical principles and the techniques of mathematics are used to accomplish the assignments. Technical supervision of this program is supplied by the Weapons Research Division, Directorate of Research, Chemical Warfare Laboratories. Mr. Milton Cutler, Chief of the Weapons Research Division, is the Project Officer.

A supplemental agreement was executed to permit the investigation of additional problems. New tasks were assigned, and the time of performance was extended to 31 August 1957. The guidance was changed to emphasize the generation of information needed in establishing the design criteria for new weapons.

This report reflects the thinking and planning as of 31 December 1956, and has not been modified by later considerations or agreements.

II. SUMMARY OF PROGRESS

A. Task II - Use of CW Agents in Recoilless Rifle Ammunition for Defeat of Field Fortifications (Fred B. Smith)

1. [illegible]

This is a continuation of previously assigned work. The purpose of this task was to determine the feasibility of [illegible] toxic-filled ammunition fired from recoilless rifles to neutralize field fortifications. The need for a lightweight infantry weapon able to overcome enemy personnel protected by field fortifications, or other expedient shelter, has long been recognized as a serious problem. Recoilless rifles provide a means for delivering accurate fire at distances greater than the effective range of small automatic weapons. Toxic agents provide a means for attacking the personnel within the protecting structure without breaching the walls. This task was to determine how effective chemical shells delivered by recoilless rifles may be, and what characteristics may be desirable in this type of shell.

2. Compendium of Previous Work

Work previous to this period included a rather comprehensive survey of the mission, features and vulnerability of field fortifications, together with the situations and conditions in which the various types of protective installations might exist. Similarly, small unit tactics were studied in order to establish realistic limits and conditions governing the possible use of recoilless rifles for the defeat of this type of hard target. Requisite background information concerning recoilless rifles, their ammunition, and characteristics of chemical munitions was obtained. All of this has been discussed in prior reports issued under this contract.

To establish a procedure for computing dosages inside the fortification, and to obtain an initial estimate of dosages which might be expected, some preliminary design investigations were made. Study of 57mm ammunition indicated that a spin-stabilized shell containing 100 grams of GB and an axial burster could be made, and should perform satisfactorily. Such a shell bursting on the inside of a typical field fortification element should produce dosages lethal to masked personnel by percutaneous action of vapor. However, at a 2000-yard range, an excessive number of rounds must be fired to obtain a reasonable expectation that one or more rounds will enter a one-foot by three-foot firing embrasure. Therefore, further study of the 57mm round was deferred, and effort was concentrated on determining the effects to be expected from 106mm ammunition.

The dosages to be expected from a single 106mm round, filled with 3 pounds of GB, and having an axial burster containing 0.6 pounds of high explosive, were investigated. This work indicated that dosages lethal by inhalation may result from a single shell impacting outside but near the structure. Under certain conditions, percutaneously lethal vapor dosages may result inside of the structure from a single shell. However, with the usual shell designs, the dispersal of agent by the explosion is such that, generally, a very small fraction of the total agent charge will be introduced into the fortification. Therefore, the probability of neutralizing a fortification by a single GB shell, of the usual design, is very small.

3. Progress During This Period

The previous work demonstrated the need for more information concerning the processes of explosive dissemination of liquids, and formation of the initial agent cloud. The target region where impacts will occur most frequently is sufficiently close to the fortification opening that agent introduced by the momentum of the particles will be the major contribution to the total dosage. Both the short term and total dosages resulting from agent introduced during the formation of the initial cloud will be strongly dependent on the quantity and particle size of agent entering in the liquid phase as well as that quantity entering as vapor. Thus, knowledge of the motion and distribution of agent during the time following initiation of detonation is important to the estimation of effects to be expected from hits close to the opening.

It appears to be desirable to use a dissemination system which produce a more dense cloud than those resulting from munitions designed for maximum area coverage. It would also be desirable to direct the region of maximum concentration of agent toward the opening. Munitions using axial central bursters for dissemination of the liquid fill do not produce the most desirable distribution of agent for this purpose, nor do shapes being investigated for increasing initial area coverage. Thus, information is required on which to base designs to be investigated in the task.

The shape and concentration of agent within the initial cloud, together with interactions between successive bursts, become important in estimating effects from one to six rounds successively impacting on the outside of the structure. Here, concentration distribution and its variations with impact conditions and time may differ greatly from any simple model which is not based on experimental evidence. For this, and the reasons previously indicated, a search of the literature available at the Chemical Warfare Laboratories Technical Library, and a review of the ASTIA Index was conducted to find information available on explosive dissemination of liquids. Unfortunately, no information directly applicable to this task was found.

A review of the procedures used in the previous work was started. This considered the validity of simplifying assumptions made together with the manner in which these simplifications affect dosage estimates. An attempt was made to determine a more secure physical basis for this part of the task. Refinements were introduced where these would improve the reliability of results.

Two statisticians were assigned to work on this task late in December 1956. Work started on estimation of probabilities of killing the fortification by single shots fired from various ranges and at several positions for each range. Equations were formulated for investigation of effects from multiple impacts.

The activity on this task was reduced during this period. The administrative reasons were: change in project organization, changes in other task assignments, changes in emphasis on type of work to be performed, and project funding during the first portion of the period. However, the more important reasons were technical. The task had progressed to a stage where the preliminary mode of attack was formulated and the first estimates of dosages were made. Therefore, it seemed advisable to review the basic premises and consider the basic model before starting the more detailed computations. It was particularly necessary to check the physical reasoning before entering statistical and probability considerations. It was also thought that a comprehensive review of literature, in light of our increased knowledge of the relative importance of the various factors, should be made. Although a continuous survey of document listing was made for the entire project, titles and abstracts are often misleading, so critical articles may be neglected. The literature survey was completed with negative results.

4. Plans for Future

The computation of probabilities of achieving given dosage levels with single rounds was continued. The work in mathematical statistics required for solution of the successive impact problem was continued until dosages [illegible] the bunker from one to six rounds were computed for the 106mm rifle.

An attempt was made to arrive at shell design which would be more effective than a central burster configuration. While this was based on meager basic data, and no specific test results, it should be helpful in suggesting designs to be checked by experiment. Desirable initial dispersion patterns were suggested.

The feasibility of using toxic-filled ammunition with the platoon anti-tank weapon were considered. It was expected that both the information and methods developed in the study of the 106mm shell would be applicable to the investigation of the 90mm shell. This weapon appeared to be a promising means by which the small infantry unit might overcome field fortifications. While its low velocity (700 ft/sec) and small shell (7 pounds) are not desirable, the weapon is light in weight, may be readily manhandled, and should meet mobility and availability requirements. Specific details are required before toxic ammunition may be considered.

B. Task III - Exploitation of Toxic CW in Tactical Situations Using Ground-to-Ground Munitions (Arthur Horberg)

1. Definition of Task

Under Task III, the Armour Research Foundation was asked to determine tactical situations of ground warfare in which the use of toxic weapons may be advantageous. This task was to generate information to guide the munitions research and development program. From this work, new weapons, new uses for toxic agents, or means for overcoming limitations of weapons systems and their application were to be suggested.

Task III was terminated at the Steering Committee Meeting held at Chemical Warfare Laboratories on September 26, 1956.

2. Work Accomplished Prior to this Period

Prior to June 30, 1956, information pertinent to this work was gathered from Chemical Corps Operations Research Group, Continental Army Command, Combat Operations Research Group, Operations Research Office, Engineer School, Engineer Research and Development Laboratories, Army Map Service, Infantry School, Chemical Corps Training Command, and Chemical Corps Plans and Doctrine Division. One tactical situation, which was developed as a problem by the Infantry School at Fort Benning, Georgia, was studied in detail.

To fulfill this assignment it was intended to construct or describe a series of military situations representing both the present time and 1965. Intuitive judgments based on these situations were to be made concerning situations advantageous for the use of toxic weapons and techniques for their use. The intuitive judgments were to be tested by means of an evaluation program. To this end an evaluation methodology was to be developed.

One situation, developed as a problem by the Infantry School, Ft. Benning, Georgia, was studied in detail. This situation involved the ATFA-2 division in an offensive operation located in Western Germany, the objective being Trier. The procedure used was to describe the problem as it was posed and solved by The Infantry School both with and without atomics. Then toxic chemical warfare was applied to the situations from the attacker's point of view, and then from the defender's point of view. This was an extension of the School's approach, since the School considered no chemical munitions other than screening smoke.

In so far as was possible, within the limits of time and funds available for this work, methods for computing probabilities of kills and determination of criteria for effectiveness were formulated. There was not time to develop an evaluation technique whereby a weapon may be judged by its ability to enhance a complete weapons system in a tactical situation.

3. Criteria for Effectiveness

A criterion for effectiveness of a weapon should be a function of casualties, cost in manpower to produce those casulaties, cost in dollars to achieve those casulaties, and cost in tonnage to achieve those casualties. It may be argued that effectiveness is directly proportional to casualties and inversely proportional to manpower, dollars, and tonnage. Thus, the relationship may be

$$\text{effectiveness} = \frac{\text{casualties}}{\text{men} \times \text{dollars} \times \text{tonnage}} .$$

But should men, dollars, and tons be assigned the same weight? Are they of equal value in determining effectivenss? Where do you start counting men rather than the dollar value of man-hours?

These questions may be answered only when the complete purpose of the evaluation is known. The commander of a front line unit would count combat-fit men in line organizations and disregard service troops. The army commander would include all his organic personnel who are involved in

Support of the activity to determine the manpower required to complete a mission. A war resources board might place a far broader interpretation on the evaluation of each factor than a military commander would permit.

A field commander faced with the problem of supplying a unit by air would disagree; he would give gre[illegible]er weight to tonnage. On the other hand, an executive faced with the proble[illegible] choosing weapons for stockpiling would give more weight to dollar[illegible] then, the relative weight assigned to each parameter would depend on the situation, and would be difficult to ascertain, in general.

It is suggested that the criterion of effectiveness be

$$\text{Effectiveness} \begin{cases} \dfrac{\text{casualties}}{\text{men}}, & \text{if manpower is the critical factor.} \\[2ex] \dfrac{\text{casualties}}{\text{dollars}}, & \text{if the situation implies that dollars are more significant.} \\[2ex] \dfrac{\text{casualties}}{\text{tonnage}}, & \text{if the situation implies that tonnage is more significant.} \end{cases}$$

In some cases area covered with a lethal dosage may be more significant than actual casualties produced, since space buys time in which organization may be completed or protective measures be taken before combat. Obviously, a subjective decision is required for each situation.

The effectiveness of one weapon as compared to the effectiveness of another weapon has a very limited meaning. Rather, we should compare the effectiveness of a system of weapons containing the weapon in question with the effectiveness of the system containing competing weapon. The reason for this is that in any military situation no weapon is used by itself. Each weapon is used to supplement or complement other weapons. It is suggested here that the effectiveness of chemical weapons be judged in this manner. However because of the limited time available no technique was developed for doing so. It is hoped that for future work this would be done.

4. Plans for the Future

Since Task III was terminated on September 26, 1956, the only activity was preparation of a report on the work accomplished.

C. Task VII - Critical Analysis of Dissemination Program (Fred Smith)

This task was to review critically and comment on "General Plan for the Conduct of Applied Research on Dissemination of Toxic Materials" prepared by Chemical Warfare Laboratories. A draft of the report for this task was submitted during the previous semi-annual period, and was returned for revision. It was agreed that changes in format and presentation would be made. However, when the revision was started, it was found necessary to contact each of twenty-two people who had contributed to the initial effort. These specialists supplied corrections, clarification and explanation, as well as background information on the status of work in specific pertinent technical areas.

To present the work of this task in a form most useful to the reader, and to obtain the maximum benefit from the work performed, it was found necessary to rewrite the report previously prepared. The task of compiling the comments prepared by the twenty-two technical staff members may only be accomplished by a person well acquainted with the Chemical Corps program. Therefore this was a part-time activity of the project engineer in addition to work on other assigned tasks.

D. Task IX - High Altitude Spray From Aircraft and Guided Missiles (George Fejer, Robert Fisher, John Rosinski, Edward G. Fochtman, James E. Ash)

1. Statement of Problem

This task was discussed at a Steering Committee Meeting at Armour Research Foundation on 3 August 1956. Subsequently, the task was assigned at a Steering Committee Meeting held at Army Chemical Center on 26 September 1956. Task IX was defined as follows:*

Task IX (New) High Altitude Spray from Aircraft and Guided Missiles

"This task is a study directed at a determination and proposal of design criteria for spray systems capable of disseminating low volatile liquids as droplets (>3 mg) for the production of direct casualties and for ground contamination by means of aircraft and missiles. A series of curves showing the relationship among the droplet size, aircraft velocity, altitude of release of

*Chemical Corps Research and Development Command, Chemical Warfare Laboratories, Army Chemical Center, Maryland, Reference N. CMLRD-CW-R(WR) DA-18-108-CML-5507.

gross liquid, quantity and rate of flow of liquid, physical characteristics of liquid, met conditions, area coverage, and ground contamination density are required. These relationships are required for the missile system as well as for the aircraft system using flat trajectory missiles for consideration. Aircraft velocities up to Mach 3 should be considered.

On the basis of the work performed the contractor will propose design criteria for aircraft and guided missiles spray systems."

It was agreed that this work should be limited to the consideration of aircraft flying at constant altitude and velocity, and missiles having a flat trajectory during the discharge of the liquid agent.

2. Discussion of Task

This work differs from previous aircraft spray studies in many ways. The results sought oppose the purposes of most spray systems. Discrete droplets, each three milligrams or larger, are wanted to contaminate personnel in the open and the terrain. These large droplets should be dispersed, as uniformly as is possible, over a large area to yield a ground contamination density of at least 30 milligrams per square meter. It is desired that dissemination be accomplished by discharging the liquid agent from missiles or aircraft flying at high speeds. At the time of discharge, the air speed relative to the liquid is much greater than air velocities in which three milligram droplets can continue to exist. Thus, the problem is to prevent break-up of the liquid stream until conditions permit large stable drops to exist.

It is logical and expedient to consider this task in two correlated parts. The first part is concerned with tank discharge, separation of the liquid stream into particles, break up of unstable drops and other phenomena occuring before a distribution of stable droplets is obtained; these are problems in the field of fluid mechanics. The travel of these droplets through the atmosphere to the ground, the effects of meteorological conditions on the droplets and their distribution, and the prediction of ground contamination are in the field of the technology of fine particles.

Task XII, Production of Toxic Rain, had as its objective the same type of terminal effects. Both of these tasks were investigations of means for producing casualties, or denying terrain, by liquid drops falling freely through the air. The mechanisms which produce and distribute the drops, and the military uses for each system, may be quite different than those for the other method for causing contamination. Yet, soon after the liquid is broken into drops, when stable droplets traveling at terminal speed for the particular drop size are obtained, the motions of the individual droplets may be considered independent from and unaffected by the mode of dispersal. So, that part of the problem concerned with the travel of the agent in the atmosphere, from a distribution of droplets at an altitude to the contamination pattern on the ground, may be solved by the same methods for both tasks. The work on Task IX was combined with the work on Task XII where this would conserve effort without detracting from the objectives of either task.

The study of the travel of droplets in the atmosphere is being conducted simultaneously with the investigations of the mechanisms of spray formation and means for producing large droplets under the prescribed conditions. The behavior of the droplets from the time of discharge until they reach the ground indicates the time-space-particle size distribution desired from the spray system. The design and operating characteristics of the spray system determine the dispersion of the liquid which may be accomplished within the limits of acceptable operating conditions.

3. Progress During This Period

a. Literature Survey

An extensive survey of the classified and nonclassified literature pertinent to this task was started on September 2, 1956. Subject and cross reference titles applicable to Task XII were added to the literature to be searched on November 1. The Chemistry Literature Section, which is comprised of specialists in this work, conducted the survey in cooperation with the technical personnel scheduled to accomplish the tasks. The work on Task V, together with the experience of the assigned personnel in the fields of fluid mechanics and aerosol travel, provided a background of information concerning the state of knowledge and current related activities. Thus, the number of articles reviewed and studied could be limited to those which might bring new information to bear on the specific problems.

b. Formation of Drops from Fluid Jets in Air

A jet of liquid being discharged from a spray tank will form a great number of droplets in a short time. The size and velocity of each droplet is determined by the local stresses and motion in that portion of the liquid from which it is formed at the time of its separation. Separation of each drop contributes an additional impulse to disturb the parent stream. Each droplet formed creates an additional disturbance tending to increase the turbulence of the flow of air around the jet. Thus, a wide variance in initial conditions of the droplets is to be expected, and this has been confirmed by experiments conducted with spray nozzles. The droplet density is quite high in the proximity of the main jet. Thus, there are interactions between droplets. Droplets overtake each other and collide, rebound, coalesce, or shatter depending upon the conditions of impingement. Small drops are captured to produce large drops at the same time that large drops are being deformed and shattered by drag forces. Thus, we have a rapidly changing picture until most of the drops are separated by distances which make collisions improbable.

A short time after ejection of the liquid, a relatively stable cloud of droplets is obtained. Each droplet in this cloud will be traveling at a speed close to its terminal velocity. Droplets larger than the maximum size that can subsequently exist at this velocity will break into much smaller droplets. The smaller droplets will move more slowly than their parent, because they were slowed in the process of their formation and the retarding effect of air resistance is larger. If we know the distribution of droplets in this cloud, ground contamination patterns may be predicted. These may be computed by procedures for computing aerosol travel due to atmospheric winds. Analytical procedures for determining this distribution from fundamental principles do not exist.

c. Study of Spray Formation

An analysis based on empirical studies of spray formed by small pneumatic jets was started. The formulae developed by Nukiyama and Tanasawa and results of the investigations by Merrington and Richardson were used as the basis for this part of the work. These apply directly to the spraying of liquids into air from jets less than 1/2-inch in diameter. Later attempts were made to account for the effect of jet thickness in protecting the core of the jet from the disruptive forces of the air by applying the techniques used in G.I. Taylor's Porton paper of May 1951.

It was too early to predict the results of the first analysis, but it was expected that unusual methods will be required to prevent excessive breakup of the liquid. Hydraulic nozzles, which are poor atomizers, may be more suitable than present spray nozzles. Therefore, an analysis of drop size distributions which may be expected from hydraulic nozzles was planned. Reports were ordered, and available literature was studied to gather the information necessary for starting this work.

d. Droplet Trajectory and Ground Contamination

This part was concerned with the aerosol problem and the behavior of the aerosol which forms at 1000 feet above the ground. It was not concerned with the mechanism by which these drops are formed. The ground contamination was calculated in such a manner that it was possible to obtain the rate of liquid release of a given size distribution for any ground contamination level desired.

E. Task X - Ground-to-Ground Rockets for Large Area CW Coverage
(Fred B. Smith, Harold D. Black)

1. Statement of Problem

This task was assigned at the Steering Committee Meeting held on September 26, 1956. The definition of the task is quoted from the letter dated 17 October 1956. Reference No.CMLRD-CW-R(WR) DA-18-1080CML-5507.

"This is a newly assigned task requiring that a study be conducted to determine and propose design criteria for rocket systems to disseminate low volatile liquids as droplets (>3 mg) for direct attack of personnel as well as for ground contamination.

"This study should be conducted by examining the relationship of variables such as altitude of release of liquid, method of release of liquid (emphasis should be placed on base ejection type), velocity of rocket, physical characteristics of liquid, droplet size, met conditions, ground contamination density, and area coverage. Advantage will be taken of field test data obtained by the British in their work on the 25 pounder base ejection shell.

"It is required that the contractor propose design criteria for this system including size, capacity, altitude of release, burster mechanism, rate of fire, aiming error, etc."

2. Discussion of Task

The performance specifications and military characteristics of a weapon are functions of the target to be defeated and the operational conditions in which the weapon may be used. In this study, we shall consider only those physical factors limiting the selection of performance specifications and the manner in which these interact with the military characteristics of this type of weapon. Although they cannot be excluded from the intuitive reasoning processes, tactics, organization, economics, logistics, human behavior, etc. will be considered only to the extent that these are essential to the formation of engineering judgments. Existing knowledge and experience will guide the analysis. The results will be an engineering estimate which should provide a starting place for design, or requisite information for operational analysis.

The shape and size of the area to be contaminated is one of the most important considerations leading to the determination of an area coverage weapon system. An examination of factors involved in this problem led to the selection of the area which one battalion may occupy as suitable for use in starting this study. Recent operations research studies indicate that a battalion size organization may be dispersed over an area of approximately three million square meters The shape of this area is governed by mission, terrain, progress of battle, command decision and chance. Several shapes may be useful approximations to actual military situations. Personnel of the Operations Research Office suggested an elongated rectangular area, having dimensions 300 meters by 10,000 meters, as a convenient representation of a typical target expected to occur frequently in future combat.

It is impossible to obtain one simple target model which will adequately describe the variety of field situations. Therefore, target shapes were selected which were convenient for particular sections of the analysis It was assumed that a uniform density of contamination is desired, and that equal fractions of the target area are of equal importance. A consideration of accuracy of intelligence, speed of communications, delays between command and execution, and possible variations in deployment of the enemy will tend to justify these assumptions. So, actual distribution of men and materiel within the contaminated area does not enter this study. Similarly, degrees of protection and evasive actions possible to the enemy were not considered. The objective was to obtain a contamination density equal, or greater than, 30 milligrams per square meter with droplets 3 milligrams or larger over the target area. The minimum drop size and minimum contamination density specified by the Weapons Research Division were the only criteria for terminal effects on the target.

Rational design criteria for an area coverage rocket weapon must be based upon applicable munitions expenditure - area coverage relationships. For reasons known to personnel of the Chemical Warfare Laboratories, who are well aware of the complexities of such problems, these relationships have not yet been developed. Moreover, there was insufficient time and effort allotted to attempt specific solutions for these problems under this task. However, it was hoped that useful methods for evaluating the influence of design variables upon munitions expenditure could be introduced into this investigation. Therefore, this task was expected to supply useful pre-design information before obtaining solutions for the expenditure-coverage problem.

The design features, variations in performance, operating procedures, and conditions of use are all interdependent factors which govern the usefulness of the weapon for covering areas of specific dimensions at specific ranges. For example, for rockets of usual designs, the standard deviation in range is greater, in yards, at short ranges than at maximum range. So, while ballistic dispersion is a function of the design of rocket and launching conditions, it is also dependent upon the firing point selected. (See Fig. 1.)

3. Rocket Design

A large fraction of the effort has been devoted to consideration of the rocket warhead. The warhead is defined as the group of components which includes the agent charge, the mechanism for ejecting the liquid, the fuze, components linking the fuze and ejection mechanism to start discharge, and requisite structural parts. This is the load that the rocket must carry. It is an important group contributing to the particle size distribution and distribution of agent on the target. However, before the design and functioning

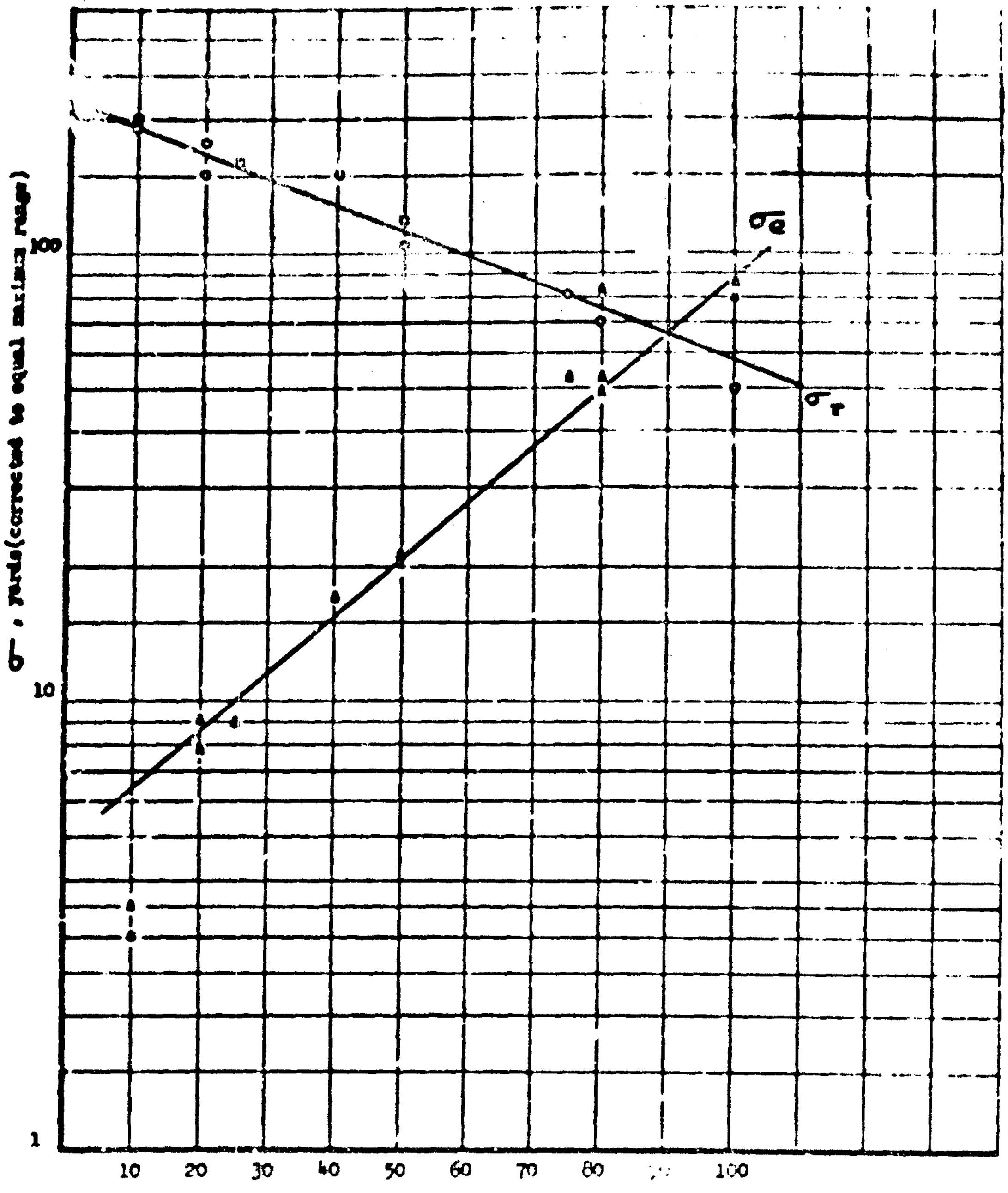

Fig. 1 BALLISTIC DISPERSION OF FIN-STABILIZED FREE ROCKETS

of warhead components may be studied, it is necessary to know the limiting conditions under which these parts may be required to operate. Therefore, some general rocket calculations were started. These were simply to provide rough estimates based on the combination of experience, empirical information, and basic equations. They served to indicate the attitude and velocity of the rocket at the time when discharge is desired, the ratio of payload to rocket weight for a given maximum range, etc. Such general considerations are an important part in the early phases of work.

4. Plans for Future

The design of the rocket is intimately related to the method of ejecting the agent and the ground contamination produced. The angle of fall and velocity of rocket during ejection are important to the determination of the ejection system, fuze functioning, particle size distribution and ground contamination pattern. The ejection mechanism and agent charge are the payload that the rocket must be designed to carry. Therefore an investigation of the area contaminated by a single rocket was planned for in the next portion of the work. The contamination produced by different ejection systems was investigated, as well as the ground coverage produced by groups of rockets. Investigation of possible rocket designs proceeded simultaneously with consideration of the area coverage problems. Base ejection systems were studied before proceeding to other dispersal methods. Both time and variable time fuzes were considered. Work on rocket and launcher design was programmed to supply information requisite to the ground contamination problem.

F. Task VI - New Concepts for the Optimim Delivery of CW Agents

1. Statement of Problem

This task was assigned at the Steering Committee Meeting held on September 26, 1956. The definition of the task is quoted from the letter dated 17 October 1956. Reference No. CMLRD-CW-R(WR) DA-18-108-CML-5507.

"This task is designed to provide the contractor with the necessary degree of freedom for examining and proposing at his discretion various types of delivery systems for CW agents.

"Based on the experience gained by the contractor during the course of the existing contract, contacts with other DOD agencies, and its own ingenuity,

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the Armour Research Foundation will propose concepts for promising dissemination and dispersion systems for toxic CW agents. The concepts proposed will be supported by theoretical considerations."

2. <u>Discussion of Task</u>

A dual approach to the accomplishment of this assignment was made. First, during the planning and performance of the work for each assigned task, conscious reflection concerning the objectives and means for accomplishing the desired results was employed. Critical thinking about the task as defined leads to conjecture concerning different objectives as well as alternative means for accomplishing the stated objective. In addition to promoting better understanding of the task, this type of thought engenders the type of dissatisfaction that is the incentive for invention. Also, as the work on each task progresses, obstacles are recognized, and ideas for surmounting or avoiding these difficulties are suggested. This leads to the discovery of new processes and new methods. Finally in the review of the work accomplished, new uses for the results, as well as other methods for achieving these results, are considered. Wherever the schedule permitted, ideas directly related to an assigned task were investigated. However, ideas have been generated which are interesting but outside of the scope of assigned work. These diversions, which may have greater potential value than the work leading to their inception, were studied and developed under this task. The most valuable inspirations for constructive thinking may be expected from the work in progress.

The other approach to new concepts is through group meetings held specifically to generate ideas. These gatherings follow the general procedures widely publicized in the current popular literature under such titles as "group ingenuity", "creative thinking", "idea sessions", "brain-storming", etc. In this method, a problem is presented to several people simultaneously. The suggestions, ideas, and approaches from individuals having different training and experiences cause an interplay which results in different procedures, or combinations and permutations of processes which would not be [illegible] a broad attack upon the problem and opens new avenues of approach to each of the individual members of the team.

Two idea-generating sessions were held. Ten people attended the first meeting, and twelve attended the next. Thus twenty-one people were asked to suggest concepts for the delivery, dissemination or use of CW agents. These people had different backgrounds as well as various degrees of knowledge and experience concerning chemical warfare. Each person received a brief statement of the purpose of the meeting in advance of the session he attended. The first ten minutes of each introductory meeting were devoted to a very brief general summary of chemical warfare. This was followed by ten minutes of questions and answers. Forty minutes were spent attacking specific problems. Then the people attending were urged to continue thinking about the problems discussed. The meetings were concluded by asking for brief memoranda covering ideas obtained after the meeting or too late for presentation during the session.

Many of the ideas presented during the initial imaginative sessions were old, and have been considered, exploited or rejected by the Chemical Corps. These were not discouraged. It appears that a necessary development in thinking about any subject is the reconstruction of at least part of its history. An attempt was made to encourage variations, extrapolations, related concepts, [illegible] irrelevant ideas from the discussion of each known or previously discarded suggestion. An effort was required to counter the effects of critical remarks and convert such comments into the basis for constructive thinking. Fortunately the more erudite members provided comments helpful for moving the discussion into imaginative areas and away from time-consuming disputation. These sessions resulted in interesting suggestions. They also served the purposes of introducing the subject matter and initiating imaginative thought.

Twelve of the people who attended the first idea-generating sessions were contacted for additional ideas and developments from suggestions presented at the meeting. While this is a time-consuming process, it is worth the effort required to contact each individual. The ideas gathered in the follow-up process are less plentiful, but each is more adequately considered and more cogently presented than the sentence or two stated at the meeting. It was too early to evaluate the merits of any of the suggestions at this writing.

3. New Concepts

a. Related to Obtaining Correct Drop Size Distribution of Agent from an Aircraft Spray or Hoppers

1. Use carriers of proper size and of a variety of geometries; the agent adhering to the outside of the carriers.
2. Encapsulate the agent in containers of a variety of shapes; the capsules to shatter on impact with personnel or the ground.
3. Freeze the agent into particles of proper size.
4. Freeze the agent into a rod and discharge through a crushing mill to produce random particles of the correct size distribution.
5. Freeze the agent into droplets and coat with a more volatile material. Disperse these pellets at temperature where the agent is a liquid carried in a frozen container. The container would melt and disappear before the stable drop impacted.
6. Manufacture synthetic thistle down and coat with agent.
7. Dip maple seeds in agent.

b. Related to Self-Dispersing Bomb Shapes

1. Construct bomblets with folding rotary wings similar to helicopter wings. High lift may be obtained without excessive rotational speeds. Open the container at the correct height and rotational speed to obtain the proper particle size distribution for optimum ground contamination.
2. Construct bomblets of shape similar to maple seeds. Make the bomblets of different materials having different masses to obtain the desired distribution.
3. Construct bomblets which fall with random orientation. Incorporate small rocket thrust units in each bomblet. Ignite thrust units after a suitable time delay to obtain random orientation of thrust.
4. Similar to (3), but incorporate random ignition time.

5. Put a heavy stake or spear on bomblets, so they will fall with the spear oriented to stick into the ground, roof tops, etc. Place a rotating disc-shaped container of agent on the stake. Rotation is to be produced by small rocket thrust units which will be ignited when the stake strikes the ground. The rotation will spray fine particles of agent and the distribution will depend upon the rotational speed.
6. Construct rubber bomblets that will bounce on impact and be fuzed to ignite a pinwheel rotational device as above. The ball will spin at a rapid rate to disperse liquid agent while it is bouncing into the air.
7. Construct bomblets with rotational device as above which will "skoot" along the ground spraying agent.
8. Drop small mechanical toys with propellant-actuated spray tanks to be driven along the ground by the thrust produced by the liquid jet.
9. Put thrust unit in bomblet fuze, so the bomblet will burst in air.
10. Use frangible bomblets to impact on rooftops, trees, foliage, etc.

c. Related to New Munitions

1. Develop inert reagents which will react with the products of explosion under the conditions of an explosion to form extremely toxic compounds. Thus any HE shell may be made into a toxic munition by incorporating the inert reagent into the explosive.
2. Incorporate reagents into fuels to produce more toxic products from incendiary munitions.

G. Task XII - Investigate the Feasibility of Producing "Toxic Rain" (John Rosinski, Robert Fisher)

1. Statement of Problem

Task XII was assigned because there is a desire to cover large areas suddenly with a shower of toxic agent dropping out of the sky, like a gentle rain falling from the clouds. This work is preliminary to a system for sprinkling V-agents on personnel, equipment, and terrain in the insidious manner of a sudden rain that wets unwary people. The system should be noiseless and the attack difficult to detect. Debris from containers, other objects or phenomena that could identify the type of attack should be kept far from the target area. Minute quantities (3 milligrams per man) of the V-agents are lethal. Consequently, this type of attack might achieve such complete surprise that it would be undiscovered until its effects were observed.

This task was assigned at a Steering Committee Meeting held at Army Chemical Center on 26 September 1956. It was defined as follows:*

Task XII (New) Investigate the Feasibility of Producing "Toxic Rain"

"This is a new task requiring that a study be conducted to determine the feasibility of producing an effective rain of toxic agent over large areas for the purpose of producing direct casualties as well as for ground contamination. The study will include, but not be limited to, the following parameters:

a. Optimum area for contamination
b. Quantity of agent required
c. Droplet size (> 3 mg)
d. Altitude of release
e. Met conditions

"It is required that the contractor determine and propose design criteria for a system which will accomplish the desired end results with primary emphasis on those systems which are relatively soundless upon functioning."

Personnel of the Chemical Warfare Laboratories expressed the opinion that the objectives of this task might be achieved by a very simple device. It was suggested that a suitable distribution of agent might result from opening a suitable container of liquid at the proper height. Therefore, the Project Officer requested that the work be started by investigating the ground contamination to be expected when a mass of liquid is released from a falling container at very high altitudes.

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* [illegible] Chemical Warfare Laboratories, [illegible], Reference No. CMLRE-RD-R-DA-18-108-CML-5507, dated 17 October 1957.

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2. Discussion

In order to place an effective contamination density on the target area, the agent must be released in the correct place, under conditions that will form the correct drop sizes, for the winds existing during the fall of agent to disperse these droplets and carry them to the target. The wind velocity profile will be one of the limiting factors considered in the use of any device for distributing drops of liquid. The importance of wind will increase as height of release of the liquid, and therefore time of travel of the droplets, is increased. The velocity profile is related to local ground wind, season of year, latitude, local terrain, and general weather conditions. The distribution of agent is dependent upon the fluctuations from the average velocity gradient as well as local turbulence during the travel of the droplets. The prediction of wind is an old and continuing Chemical Corps problem which is pertinent to the prediction of the travel and fallout of all airborne materials. Difficulties in wind prediction may be minimized by judicious choice of targets or by continuous monitoring and forecasting of conditions in potential target areas.

The liquid studied has the following properties at 25 °C. The properties of water are listed for comparison.

	Agent	Water
ρ, density (gm/ml)	1.0	1.0
σ, surface tension (dyne/cm)	31.6	70.0
μ, viscosity (poise)	0.10	0.01
vapor pressure (mm of Hg)	0.0015-0.003	23.7

3. Progress

During this period the downwind drift and time of fall of droplets was calculated, the evaporation effects were evaluated, and equations for computation of ground contamination were derived.

Calculations of the evaporation from 1 mm diameter drops falling from 5000 meters indicated that the weight loss would be of the order of 0.01 per cent and could be neglected for this study.

Wind velocity profiles received further study and it appeared that the velocity profile would be one of the limiting factors to be considered in the operational use of sprays. The velocity profile is a function of local ground wind, latitude, season of the year, terrain, and probably general weather conditions. Thus it appears that it would be extremely difficult to predict the velocity profile over the target at the time of attack.

For purposes of this study a reasonable velocity profile was assumed. Equations for computation of ground contamination by drops of discrete size ranges released at 400 meters and 5000 meters were derived. Programming of the calculation of ground contamination for machine computation was started.

Difficulty was encountered in all attempts to predict the drop size-time-space distribution of a mass of liquid released from a container fa' ing through the air. If suitable drop size distribution data are available, attempts will be made to conduct the ground contamination analysis for the specific size distribution.

III. CONCLUSIONS

The search for data pertinent to the work on this project indicates the need for fundamental investigation of the behavior of liquid agents under the conditions in which they are disseminated from munitions.

IV. RECOMMENDATIONS

Since this work is continuing, no recommendations will be made at this time.

END